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(45) **Date of Patent:** Jan. 12, 2016

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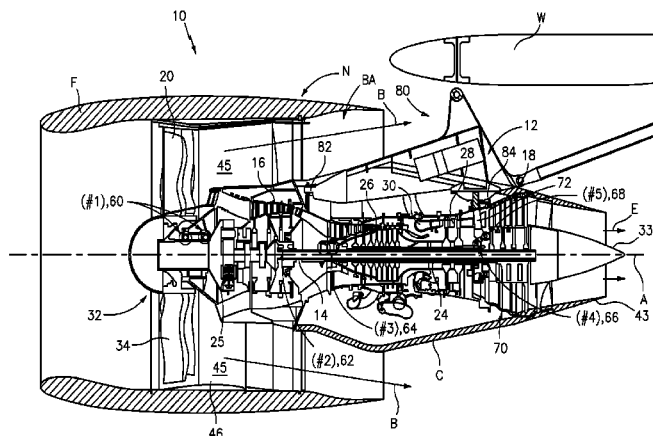
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PC

(57) **ABSTRACT**

A thermal management system includes at least two of a multiple of heat exchangers arranged in an at least partial-series relationship.

25 Claims, 6 Drawing Sheets



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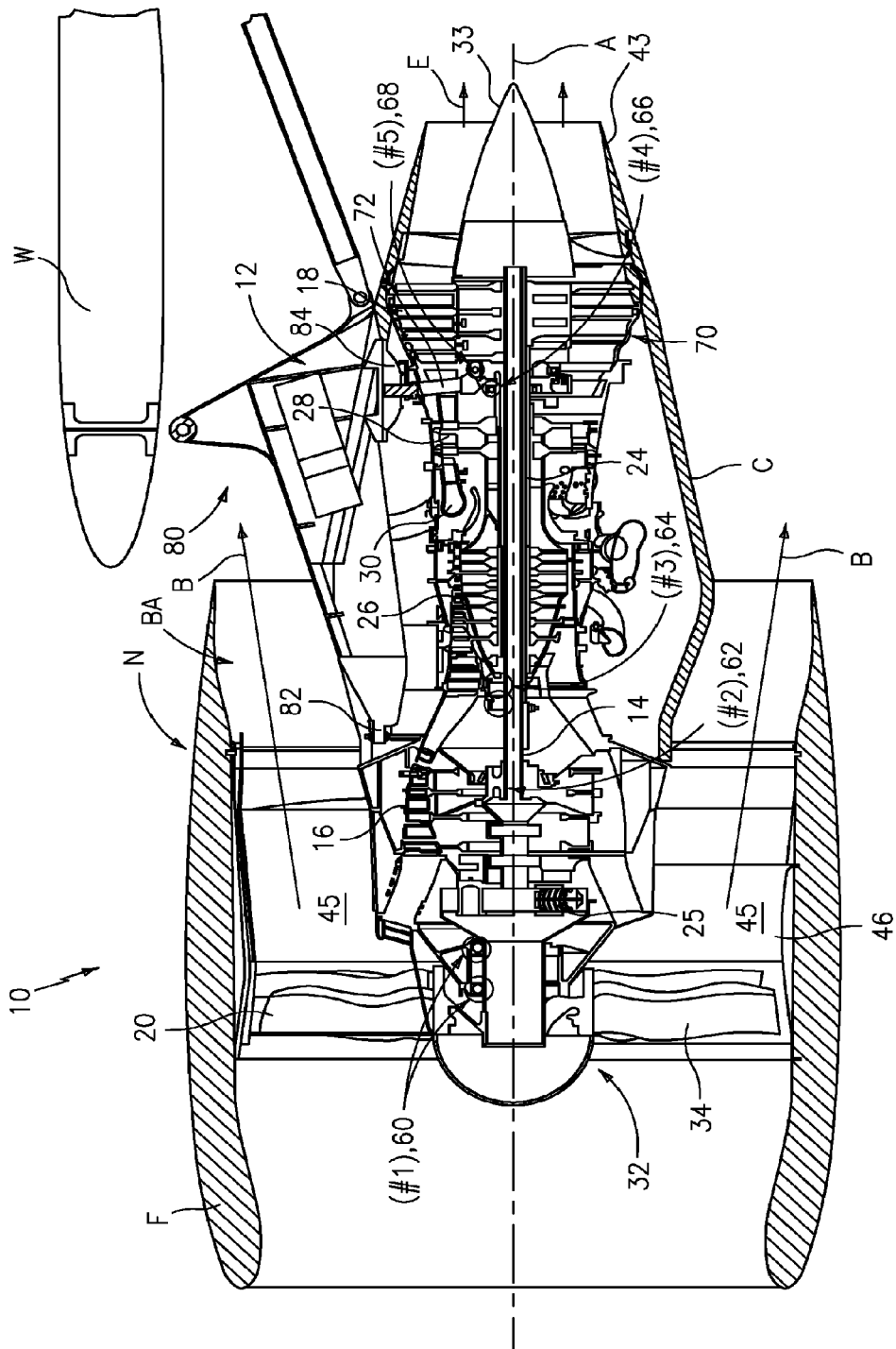


FIG. 1A

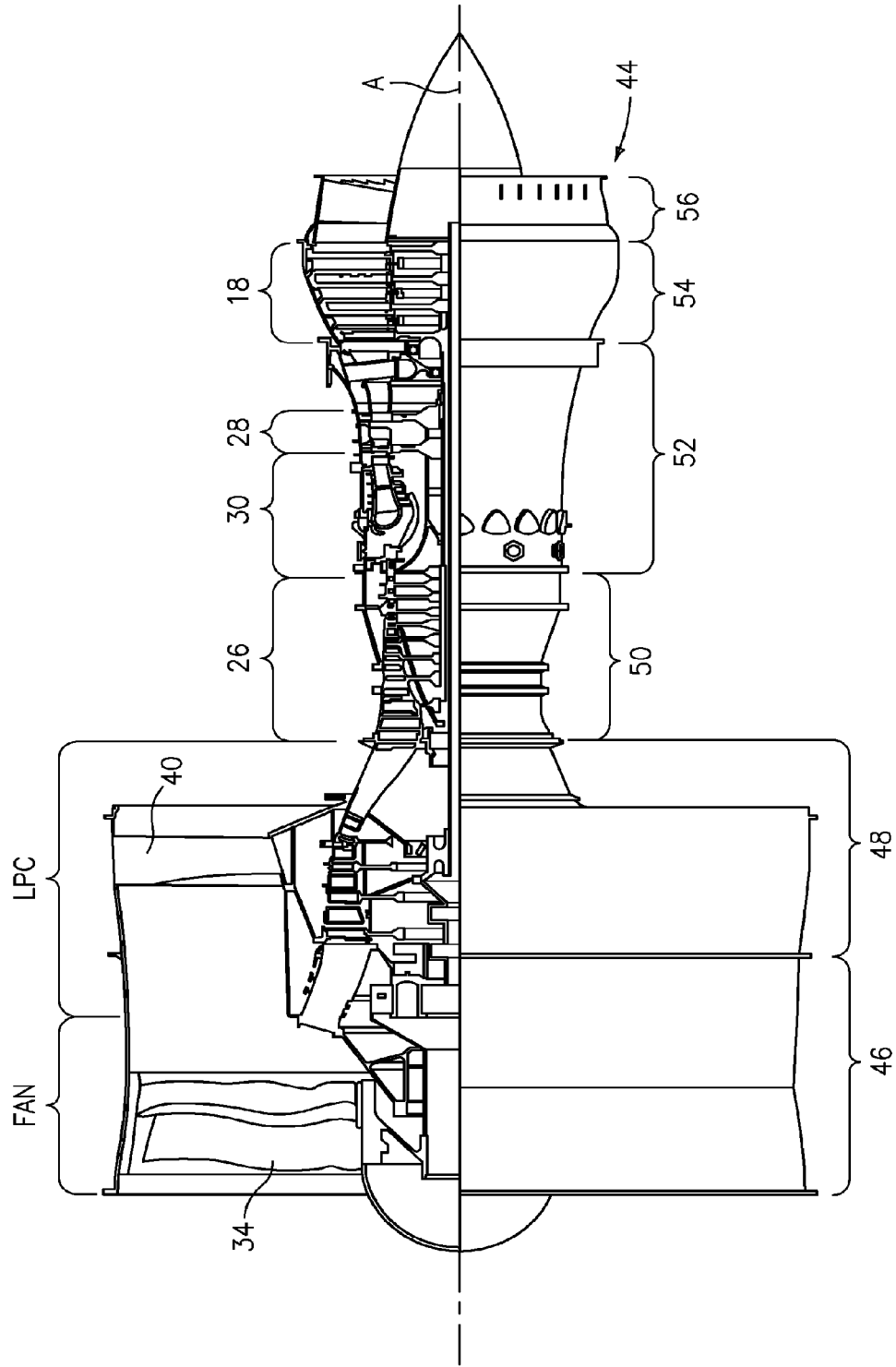


FIG. 1B

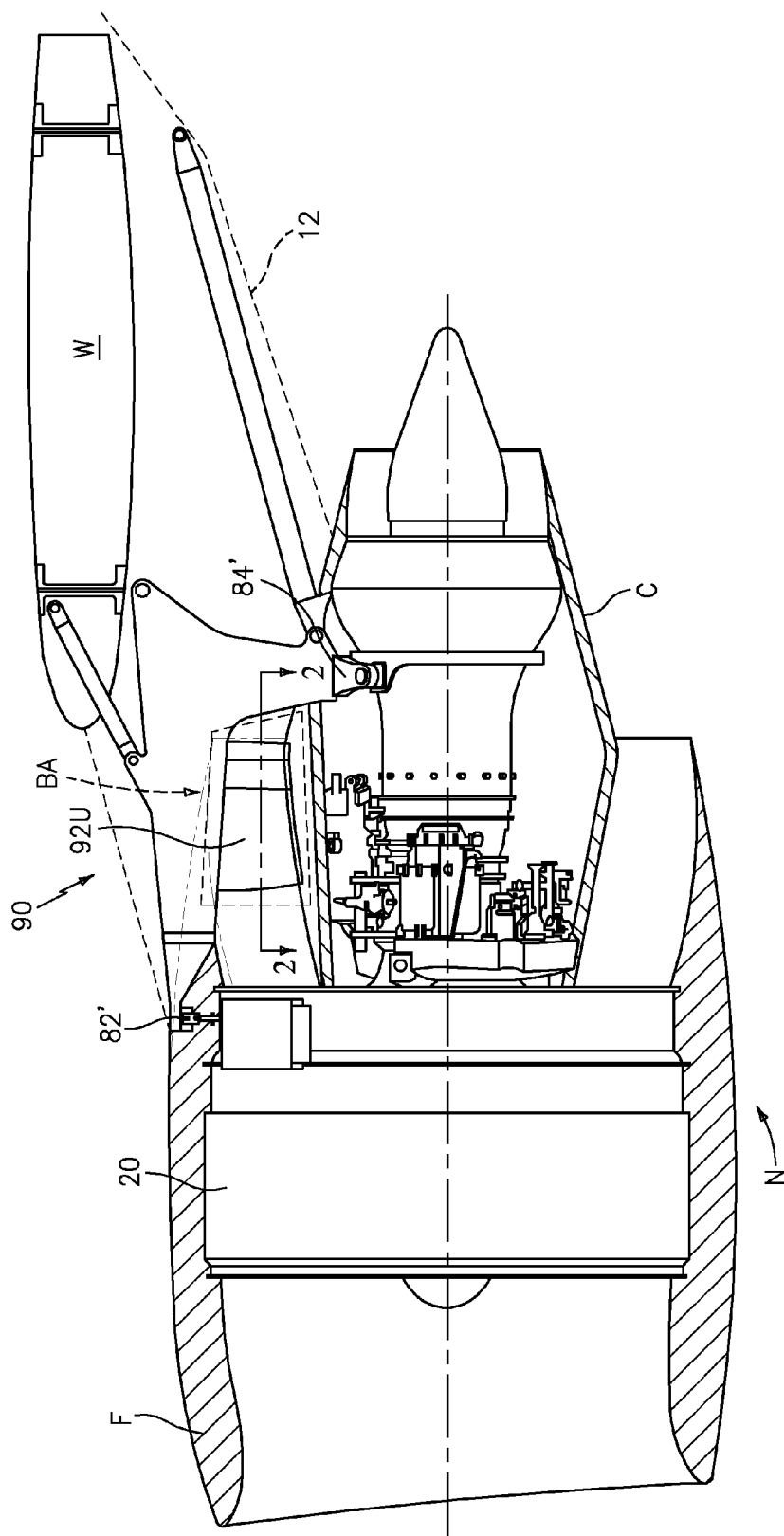


FIG. 1C

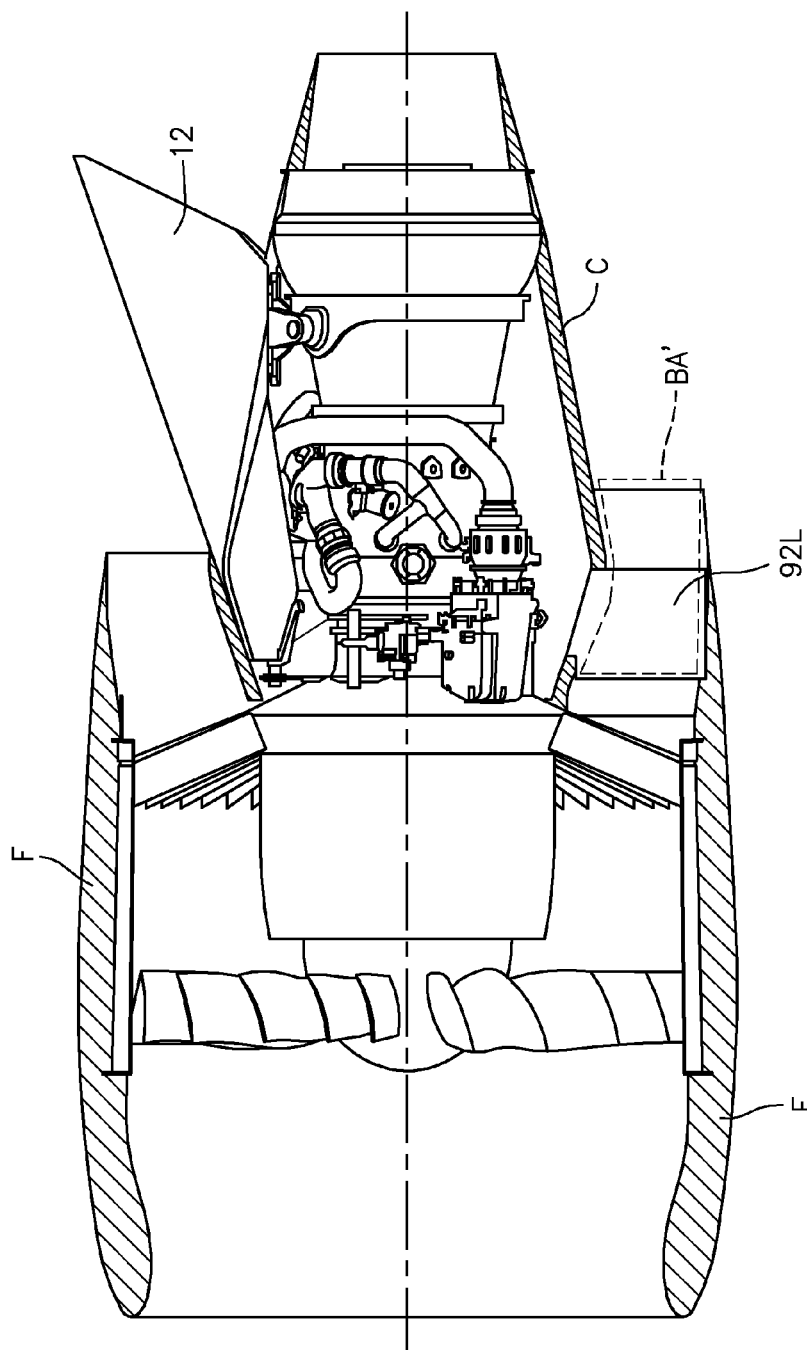


FIG. 1D

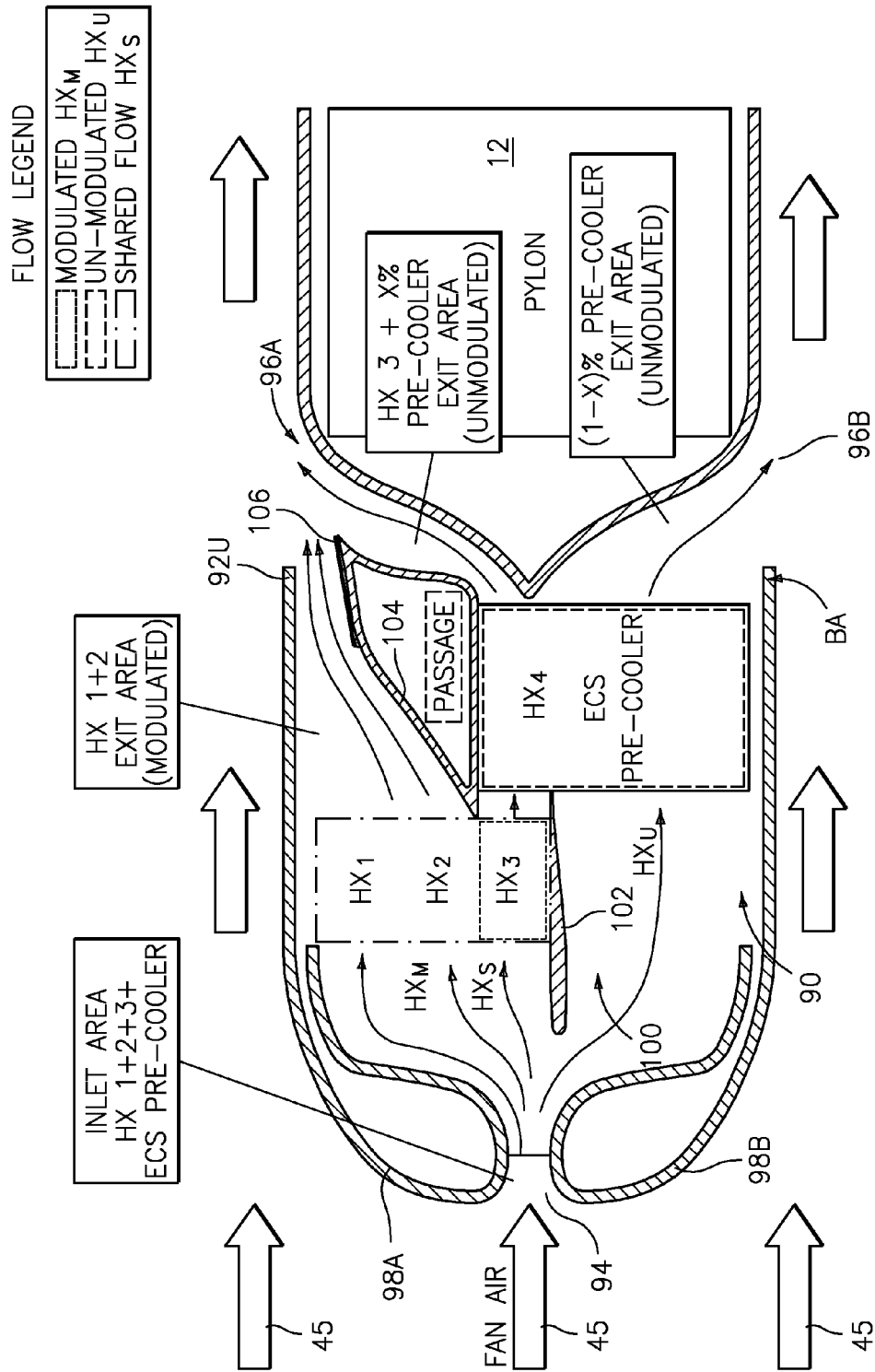


FIG. 2A

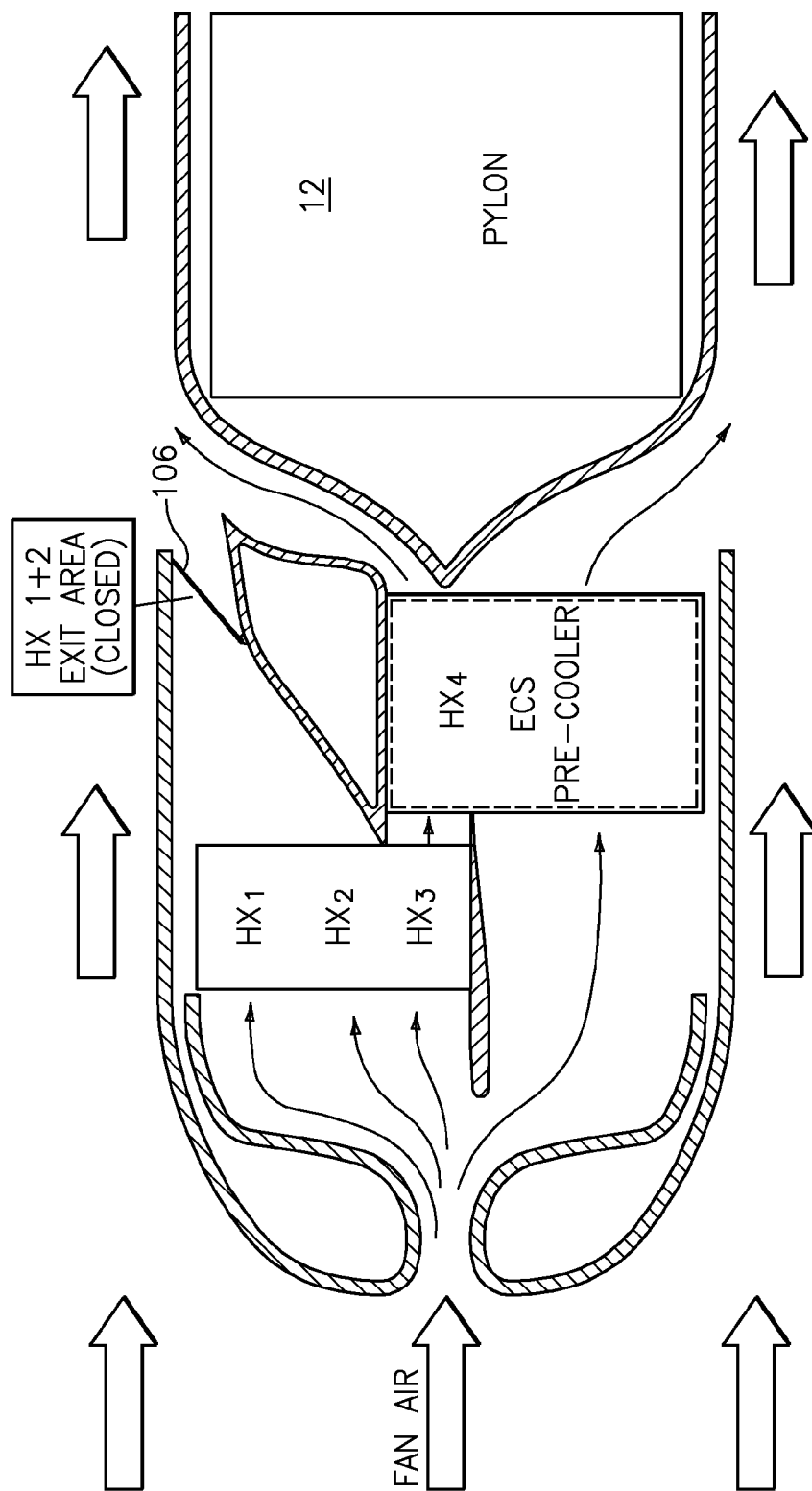


FIG. 2B

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SHARED FLOW THERMAL MANAGEMENT SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to Thermal Management Systems (TMS) with a shared heat exchanger flow.

Thermal Management Systems (TMS) include heat exchangers and associated equipment which exchange gas turbine engine heat with an airflow or fuel flow. Gas turbine engine architecture typically dictates TMS heat exchanger placement.

Conventional TMS heat exchanger locations may partially interrupt the engine thrust airflow and reduce engine efficiency. One conventional TMS heat exchanger placement is typically within a core cowl area and axially deep within a fan cowl. The heat exchanger airflow is ducted inward toward the engine centerline through the heat exchanger, then ducted outward to merge with the bypass flow. Such ducts may be relatively long and serpentine to guide the heat exchanger airflow away from, then back into the bypass flow. This location may also introduce mixing losses which may further detract from engine efficiency.

Heat exchangers are traditionally placed at separate locations within the engine airstreams in order to achieve efficient cooling because temperature-rise restrictions limit the placement of heat exchangers.

SUMMARY OF THE INVENTION

A thermal management system for a gas turbine engine according to an exemplary aspect of the present invention includes a multiple of heat exchangers mounted within a bifurcation area in communication with a bypass flow from the gas turbine engine, at least two of the multiple of heat exchangers arranged in an at least partial-series relationship.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the currently disclosed embodiment. The drawings that accompany the detailed description can be briefly described as follows:

FIG. 1A is a general sectional view through a gas turbine engine along an engine longitudinal axis;

FIG. 1B is a general sectional view through a gas turbine engine along the engine longitudinal axis illustrating an engine static structure case arrangement on the lower half thereof;

FIG. 1C is a general sectional view illustrating a bifurcation area;

FIG. 1D is a sectional view illustrating another bifurcation area;

FIG. 2A is a top sectional view of a thermal management system axis; and

FIG. 2B is a top sectional view of the thermal management system of FIG. 2A with a modulated flow vane moved toward a closed position.

DETAILED DESCRIPTION OF THE DISCLOSED EMBODIMENT

FIG. 1A illustrates a general partial fragmentary schematic view of a gas turbine engine 10 suspended from an engine pylon structure 12 within an engine nacelle assembly N as is typical of an aircraft designed for subsonic operation. It

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should be understood that although a particular component arrangement is disclosed in the illustrated embodiment, various pylon structures 12 and nacelle assemblies N will benefit herefrom.

The engine 10 includes a core engine within a core nacelle C that houses a low pressure spool 14 and high pressure spool 24. The low pressure spool 14 generally includes a low pressure compressor 16 and low pressure turbine 18. The low pressure spool 14 drives a fan section 20 connected to the low pressure spool 14 either directly or through a gear train 25.

The high pressure spool 24 includes a high pressure compressor 26 and high pressure turbine 28. A combustor 30 is arranged between the high pressure compressor 26 and high pressure turbine 28. The low pressure and high pressure spools 14, 24 rotate about an engine axis of rotation A.

The engine 10 in the disclosed non-limiting embodiment is a high-bypass geared architecture aircraft engine where the engine 10 bypass ratio is greater than ten (10:1), the turbofan diameter is significantly larger than that of the low pressure compressor 16, and the low pressure turbine 18 has a pressure ratio that is greater than 5:1. The gear train 25 may be an epicycle gear train such as a planetary gear system or other gear system with a gear reduction ratio of greater than 2.5:1. It should be understood, however, that the above parameters are only exemplary of one non-limiting embodiment of a geared architecture engine and that the present invention is applicable to other gas turbine engines including direct drive turbofans.

Airflow enters the fan nacelle F which at least partially surrounds the core nacelle C. The fan section 20 communicates airflow into the core nacelle C to the low pressure compressor 16. Core airflow compressed by the low pressure compressor 16 and the high pressure compressor 26 is mixed with the fuel in the combustor 30 ignited, and burned. The resultant high pressure combustor products are expanded through the high pressure turbine 28 and low pressure turbine 18. The turbines 28, 18 are rotationally coupled to the compressors 26, 16 respectively to drive the compressors 26, 16 in response to the expansion of the combustor product. The low pressure turbine 18 also drives the fan section 20 through gear train 25.

A core engine exhaust E exits the core nacelle C through a core nozzle 43 defined between the core nacelle C and a tail cone 33. A bypass flow path 45 is defined between the core nacelle C and the fan nacelle F. The engine 10 generates a high bypass flow arrangement with a bypass ratio in which approximately 80 percent of the airflow entering the fan nacelle 34 becomes bypass flow B. The bypass flow B communicates through the generally annular bypass flow path 45.

An engine static structure 44 generally has sub-structures including a case structure often referred to as the engine backbone. The engine static structure 44 generally includes a fan case 46, an intermediate case (IMC) 48, a high pressure compressor case 50, a thrust case 52, a low pressure turbine case 54, and a turbine exhaust case 56 (FIG. 1B). The fan section 20 includes a fan rotor 32 with a plurality of circumferentially spaced radially outwardly extending fan blades 34. The fan blades 34 are surrounded by the fan case 46.

The core engine case structure is secured to the fan case 46 at the IMC 48 which includes a multiple of circumferentially spaced radially extending struts 40 which radially span the core engine case structure and the fan case 46. The core nacelle C is at least partially supported within the fan nacelle by structure often generically referred to as Fan Exit Guide Vanes (FEGVs), upper bifurcations, lower bifurcations or such like.

The engine static structure **44** further supports a bearing system upon which the turbines **28**, **18**, compressors **26**, **16** and fan rotor **32** rotate. A #1 fan dual bearing **60** which rotationally supports the fan rotor **32** is axially located generally within the fan case **46**. The #1 fan dual bearing **60** is preloaded to react fan thrust forward and aft (in case of surge). A #2 LPC bearing **62** which rotationally supports the low pressure spool **14** is axially located generally within the intermediate case (IMC) **48**. The #2 LPC bearing **62** reacts thrust. A #3 high spool thrust bearing **64** which rotationally supports the high pressure spool **24** and also reacts thrust. The #3 high spool bearing **64** is also axially located generally within the IMC **48** just forward of the high pressure compressor case **50**. A #4 bearing **66** which rotationally supports a rear segment of the high pressure spool **24** reacts only radial loads. The #4 bearing **66** is axially located generally within the thrust case **52** in an aft section thereof. A #5 bearing **68** rotationally supports the rear segment of the low pressure spool **14** and reacts only radial loads. The #5 bearing **68** is axially located generally within the thrust case **52** just aft of the #4 bearing **66**. It should be understood that this is an exemplary configuration and any number or combination of bearings may be utilized.

The #4 bearing **66** and the #5 bearing **68** are supported within a mid-turbine frame (MTF) structure **70** to straddle radially extending structural struts **72** which are preloaded in tension. The MTF **70** provides aft structural support within the thrust case **52** for the #4 bearing **66** and the #5 bearing **68** which rotatably support the spools **14**, **24**.

A dual rotor engine such as that disclosed in the illustrated non-limiting embodiment typically includes a forward frame and a rear frame that support the main rotor bearings. The intermediate case (IMC) **48** also includes the radially extending struts **40** which are generally radially aligned with the #2 LPC bearing **62** (FIG. 1A). It should be understood that various engines with various case and frame structures will benefit herefrom.

The engine **10** is mounted to aircraft structure such as an aircraft wing **W** through an engine mounting configuration **80** defined by the pylon structure **12**. The engine mounting configuration **80** includes a forward mount **82** and an aft mount **84**. That is, the pylon structure **12** may include various braces, struts and such like which are surrounded at least in part by an aerodynamic fairing structure. The forward mount **82** is secured to the IMC **48** and the aft mount **84** is secured to the MTF **70** at the thrust case **52**. The forward mount **82** and the aft mount **84** are arranged in a plane containing the axis **A** of the turbofan gas turbine **10**. This eliminates thrust links from the intermediate case, which frees up valuable space beneath the core nacelle and minimizes IMC **48** distortion.

Referring to FIG. 1C, a shared flow thermal management system (TMS) **90** is at least partially integrated adjacent the nacelle assembly **N**, the engine pylon structure **12** and an upper bifurcation (bifi) **92U**. This area is generally referred to herein as a bifurcation area **BA**. It should be understood that the TMS **90** may be located at least partially forward of the pylon structure **12**, at least partially within the pylon structure **12**, at least partially within the upper bifurcation **92U** or any configuration thereof but still be considered as located within a bifurcation area **BA** as defined herein. Alternatively, if located within a lower section of the engine such as in a lower bifurcations **92L**, this area too may be considered as located within a bifurcation area **BA** as defined herein (FIG. 1D). That is, the TMS **90** may be arranged in various axial positions

such that a vertical plane which passes through the engine centerline **A** and the pylon structure **12** will likely also pass through the TMS **90**.

The TMS **90** in one non-limiting embodiment, includes a first heat exchanger **HX1**, a second heat exchanger **HX2**, a third heat exchanger **HX3** and a fourth heat exchanger **HX4** (FIG. 2A) in communication with the bypass flow path **45** through an inlet **94** and an exit **96**, axial and lateral space within the upper bifurcation (bifi) **92U** adjacent the engine pylon structure **12** locates the heat exchangers **HX1**, **HX2**, **HX3**, **HX4** in the bypass flow path **45**, facilitates packaging of the TMS **90** and achieves cooling airflow requirements.

The TMS **90** locates at least two heat exchangers **HX1**-**HX4**, which, when placed in a partial-series configuration, re-use the cooling airflow between the two heat exchangers (in this non-limiting embodiment illustrated as **HX3** and **HX4**) to achieve effective packaging while maintaining cooling airflow requirements. This is provided at least in part by increased-efficiency heat exchangers and the large amount of space available adjacent to the pylon structure **12**.

Referring to FIG. 2A, a set of inlet guide vanes **98A**, **98B** define the inlet **94** such that the heat exchangers **HX1**-**HX4** may be located in a common area and arranged in partial-series to share the inlet **94**. Inlet air may be split into a modulated heat exchanger flow **HXm**, an unmodulated heat exchanger flow **HXu** and a shared heat exchanger flow **HXs**. The fourth heat exchanger **HX4** in the disclosed non-limiting embodiment is an environmental control system pre-cooler, a portion of which is in the unmodulated heat exchanger flow **HXu** and a portion of which is in the shared heat exchanger flow **HXs**. It should be understood that the heat exchangers **HX1**-**HX4** may be air/fluid, fluid/fluid, or air/air heat exchangers. Air/fluid heat exchangers are typically utilized to cool engine fluids to maintain low temperatures. Fluids may be oil used to lubricate engine components such as bearings and gears, or fuel. Fluid/fluid exchangers are typically utilized to preheat engine fuel before combustion to increase cycle efficiency. Air/air heat exchangers are typically utilized to cool high-temperature engine air for use in the aircraft cabin.

The exit **96** in this non-limiting embodiment is split to communicate exit airflow from the heat exchangers **HX1**-**HX4** through a heat exchanger **96A**, **96B** along both sides of the pylon structure **12**. A vane structure **100** is located in response to desired heat exchanger airflow requirements. The vane structure **100** includes an inner guide vane **102** and an outer guide vane **104** between which the shared heat exchanger flow **HXs** is defined. The outer guide vane **104** further provides for passage of conduits, wiring harness, piping and such like between the engine **10** and the wing **W**.

A modulated flow vane **106** is located within the modulated heat exchanger flow **HXm** to shutter or modulate the exit airflow to provide a desired backpressure or other flow control through the heat exchangers **HX1** and **HX2**. That is, in one example, should the modulated flow vanes **106** be moved toward a closed position (FIG. 2B), airflow through heat exchangers **HX1** and **HX2** will decrease while airflow through heat exchanger **HX3** and **HX4** will increase. It should be understood that although a particular inlet and exit arrangement is illustrated in the disclosed, non-limiting embodiment, various inlet and exit combinations which may include combinations of multiple as well as single inlet(s) and exit(s) will benefit herefrom.

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The TMS reduces weight as TMS support structure and plumbing are minimized when the heat exchangers are placed directly in the bypass flow path such that ducting length is reduced. Each heat exchanger may also be reduced in size when located in the bypass flow path as the heat exchangers operate in a cooler environment than when placed in the engine core. Bypass aerodynamic efficiency is also increased as a reduction in mix area occurs outside the bypass duct zone. Furthermore, the overall TMS space is reduced and combined into a smaller overall volume due to close-positioning in a space with a more rectilinear shape.

It should be understood that relative positional terms such as “forward,” “aft,” “upper,” “lower,” “above,” “below,” and the like are with reference to the normal operational attitude of the vehicle and should not be considered otherwise limiting.

It should be understood that although a particular component arrangement is disclosed in the illustrated embodiment, other arrangements will benefit from the instant invention.

Although particular step sequences are shown, described, and claimed, it should be understood that steps may be performed in any order, separated or combined unless otherwise indicated and will still benefit from the present invention.

The foregoing description is exemplary rather than defined by the limitations within. Many modifications and variations of the present invention are possible in light of the above teachings. The disclosed embodiments of this invention have been disclosed, however, one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. For that reason the following claims should be studied to determine the true scope and content of this invention.

What is claimed is:

1. A thermal management system for a gas turbine engine comprising:

a bifurcation area; and

a multiple of heat exchangers mounted within said bifurcation area in communication with a bypass flow from the gas turbine engine, at least two of said multiple of heat exchangers arranged in an at least partial-series relationship.

2. The system as recited in claim 1, wherein said bifurcation area is forward of a pylon structure.

3. The system as recited in claim 2, wherein said multiple of heat exchangers are mounted at least partially within an upper bifurcation.

4. The system as recited in claim 1, wherein said bifurcation area is at least partially within an upper bifurcation.

5. The system as recited in claim 1, wherein said multiple of heat exchangers are mounted at least partially within an upper bifurcation.

6. The system as recited in claim 1, wherein said multiple of heat exchangers are mounted forward of a pylon structure.

7. The system as recited in claim 1, further comprising a vane structure which splits said bypass flow into a modulated heat exchanger flow in communication with at least one of said multiple of heat exchangers, an unmodulated heat exchanger flow in communication with at least one of said multiple of heat exchangers and a shared heat exchanger flow in communication with said at least two of said multiple of heat exchangers arranged in said at least partial-series relationship.

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8. The system as recited in claim 7, wherein said vane structure defines a first exit and second exit.

9. The system as recited in claim 7, further comprising a modulated flow vane to modulate an exit airflow of said modulated heat exchanger flow.

10. The system as recited in claim 1, further comprising a vane structure which splits said bypass flow to define a first exit and a second exit.

11. The system as recited in claim 10, further comprising a modulated flow vane to modulate an exit airflow from one of said first exit and said second exit.

12. The system as recited in claim 11, wherein said modulated flow vane is movable between an open and a closed position.

13. The system as recited in claim 10, further comprising an inner guide vane and an outer guide vane between which at least one of said multiple of heat exchangers arranged.

14. The system as recited in claim 13, wherein said outer guide vane defines a passage.

15. The system as recited in claim 1, further comprising a vane structure which splits said bypass flow to define a first heat exchanger flow, a second heat exchanger flow and a shared heat exchanger flow.

16. A nacelle assembly for a gas turbine engine comprising:

a core nacelle defined about an axis;

a fan nacelle mounted at least partially around said core nacelle, a bypass flow communicated between said core nacelle and said fan nacelle;

a multiple of heat exchangers mounted within a bifurcation area in communication with said bypass flow, at least two of said multiple of heat exchangers arranged in an at least partial-series relationship; and

a vane structure which splits said bypass flow into a modulated heat exchanger flow in communication with at least one of said multiple of heat exchangers, an unmodulated heat exchanger flow in communication with at least one of said multiple of heat exchangers and a shared heat exchanger flow in communication with said at least two of said multiple of heat exchangers arranged in said at least partial-series relationship.

17. The assembly as recited in claim 16, wherein said vane structure defines a first exit and second exit.

18. The assembly as recited in claim 16, wherein said first exit and said second exit flank a pylon structure.

19. The assembly as recited in claim 16, further comprising a modulated flow vane to modulate an exit airflow of said modulated heat exchanger flow.

20. A method of thermal management for a gas turbine engine comprising:

communicating a bypass flow into a multiple of heat exchangers mounted within a bifurcation area in communication with said bypass flow, at least two of said multiple of heat exchangers arranged in an at least partial-series relationship.

21. A method as recited in claim 20, further comprising: splitting the bypass flow into a modulated heat exchanger flow in communication with at least one of the multiple of heat exchangers.

22. A method as recited in claim 20, further comprising: splitting the bypass flow into an unmodulated heat exchanger flow in communication with at least one of the multiple of heat exchangers.

23. A method as recited in claim **20**, further comprising:
splitting the bypass flow into a shared heat exchanger flow
in communication with the at least two of the multiple of
heat exchangers arranged in the at least partial-series
relationship.

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24. A method as recited in claim **20**, further comprising:
splitting the bypass flow into a modulated heat exchanger
flow in communication with at least one of the multiple
of heat exchangers, an unmodulated heat exchanger flow
in communication with at least one of the multiple of
heat exchangers and a shared heat exchanger flow in
communication with the at least two of the multiple of
heat exchangers arranged in the at least partial-series
relationship.

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25. A method as recited in claim **24**, further comprising: 15
splitting the bypass flow upstream of the first heat
exchanger and the second heat exchanger.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 9,234,481 B2
APPLICATION NO. : 12/019837
DATED : January 12, 2016
INVENTOR(S) : Gabriel L. Suciu

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

IN THE CLAIMS:

In claim 11. column 6, line 12; delete "exist" and replace with --exit--

Signed and Sealed this
Twelfth Day of April, 2016

A handwritten signature in black ink, reading "Michelle K. Lee". The signature is written in a cursive, flowing style.

Michelle K. Lee
Director of the United States Patent and Trademark Office